



JCAA/JG-PP Lead-Free Solder Testing for High-Reliability Applications

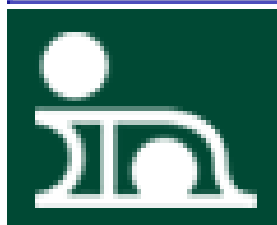
Test Vehicle Assembly

(Ana) Lety Campuzano-Contreras

BAE SYSTEMS

**IPC Printed Circuits Expo, APEX, and the Designers Summit
Anaheim, California
February 9, 2006**

Small Sampling of Team Members



Lead-Free Solder Project Goals

- Generate critical reliability data on circuit cards manufactured and reworked with lead-free and tin-lead solders.
- Provide baseline data for military and aerospace applications.

Key question being addressed: To what extent does lead-free solder affect the electrical reliability of military/space/aerospace electronics as compared to tin-lead solder?

Component Types and Finishes

COMPONENT TYPE	COMPONENT FINISH
CLCC-20	SnPb
	SAC
	SACB
PLCC-20	Sn
TSOP-50	SnPb
	SnCu
TQFP-144	Sn
TQFP-208	NiPdAu
BGA-225	SnPb
	SAC
DIP-20	Sn
	NiPdAu
0402Cap	Sn
0805Cap	Sn
1206Cap	Sn
1206Res	Sn

Components-Secondary Test Vehicle

Component Type	Component Finish
Hybrids	SnPb
	SAC
	SACB
CSPs A-CABGA100-.8mm-10mm-DC	SnPb
	SAC

Solder and Flux

Material	Wave Soldering	Reflow Soldering	Hand Soldering
Sn0.7Cu (stabilized)	X	N/A	Flux Cored Solder RMA (No Clean)
Flux	VOC Free No Clean Flux	N/A	R ROL0 Tacky Flux
Sn3.9Ag0.6Cu	Sn3.5Ag.7Cu	X	Flux Cored Solder RMA
Flux	VOC Free No Clean Flux	ROL1	R ROL0 Tacky Flux
Sn3.4Ag1Cu3.3Bi	N/A	X	0.010 Dia. Wire
Flux	N/A	No Clean (RMA)	R ROL0 Tacky Flux
Sn37Pb	X	X	Flux Cored Solder RMA
Flux	Type ORM0	ROL0	ORL0 ROL0 Tacky Flux

The recommended flux of each solder manufacturer was used.

Test Vehicles

Primary test vehicle

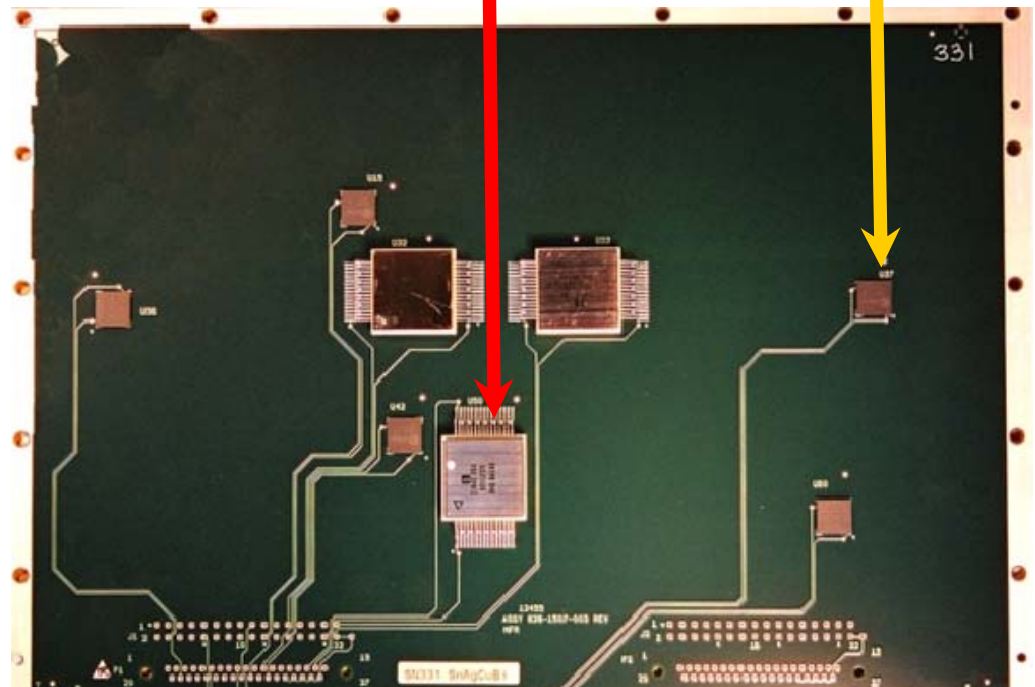
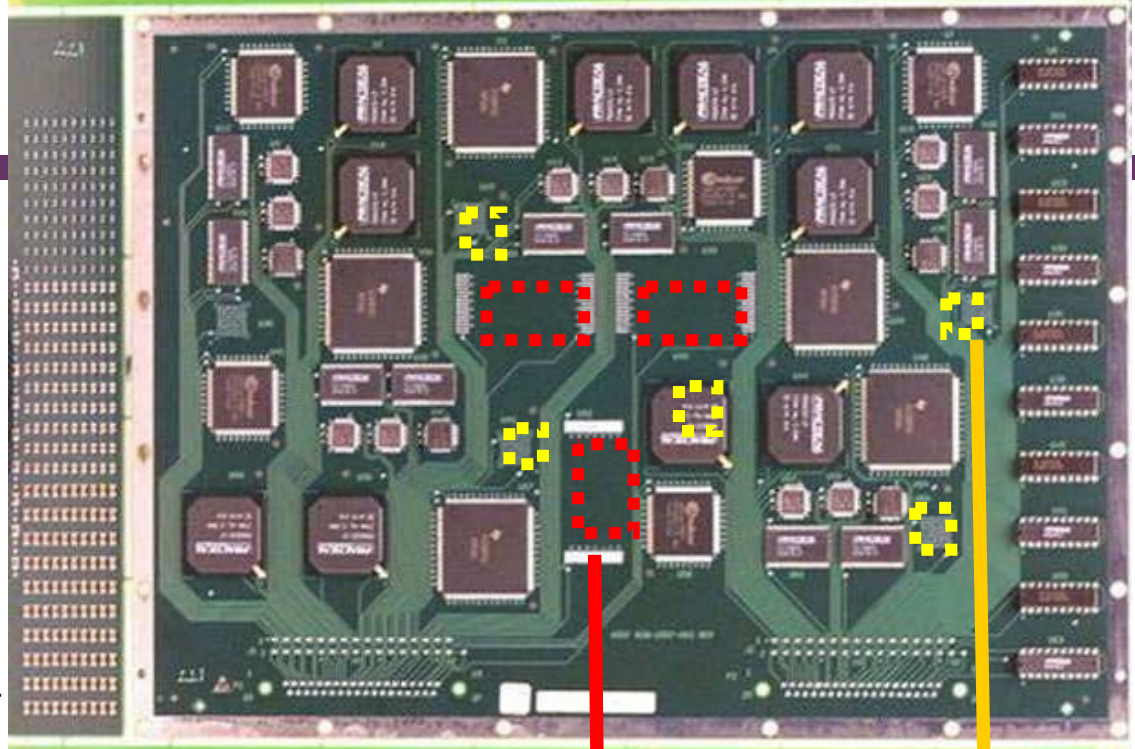
PWB

- 14.5"X 9"X 0.09", 6 layers
- Immersion silver, $T_g \sim 170^\circ\text{C}$, FR4 per IPC-4101/26
- SnPb HASL, $T_g \sim 140^\circ\text{C}$, GF (rework), FR4 per IPC-4101/21

Assemblies

- 119 Manufactured
- 89 Reworked
- 30 CSP and Hybrid

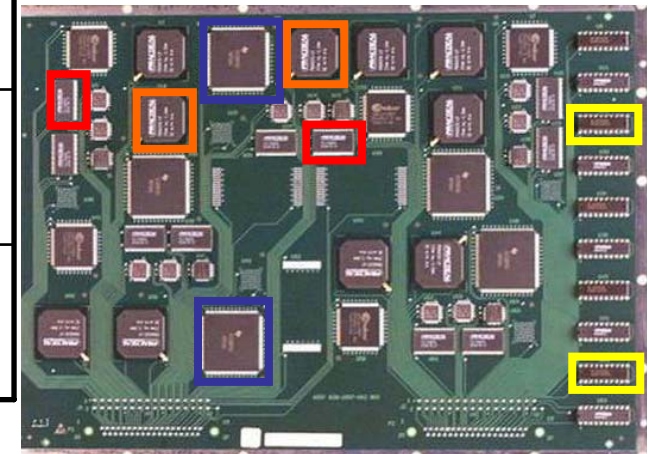
CSP & Hybrids test vehicle



Manufactured & Rework Test Vehicles

Type	Circuit Card	Reflow Solder	Wave Solder
‘Manufactured-Control’	$T_g \sim 170^\circ\text{C}$, GF Immersion Ag	SnPb	SnPb
‘Manufactured-SAC’	$T_g \sim 170^\circ\text{C}$, GF Immersion Ag	SAC	SAC
‘Manufactured-SACB’	$T_g \sim 170^\circ\text{C}$, GF Immersion Ag	SACB	SnCu
‘Rework-Control’	$T_g \sim 140^\circ\text{C}$, GF SnPb HASL	SnPb	SnPb
‘Rework- SAC’	$T_g \sim 140^\circ\text{C}$, GF SnPb HASL	SnPb	SnPb
‘Rework- SACB’	$T_g \sim 140^\circ\text{C}$, GF SnPb HASL	SnPb	SnPb

Rework with: SnPb, SAC, SACB or SnCu(Ni)

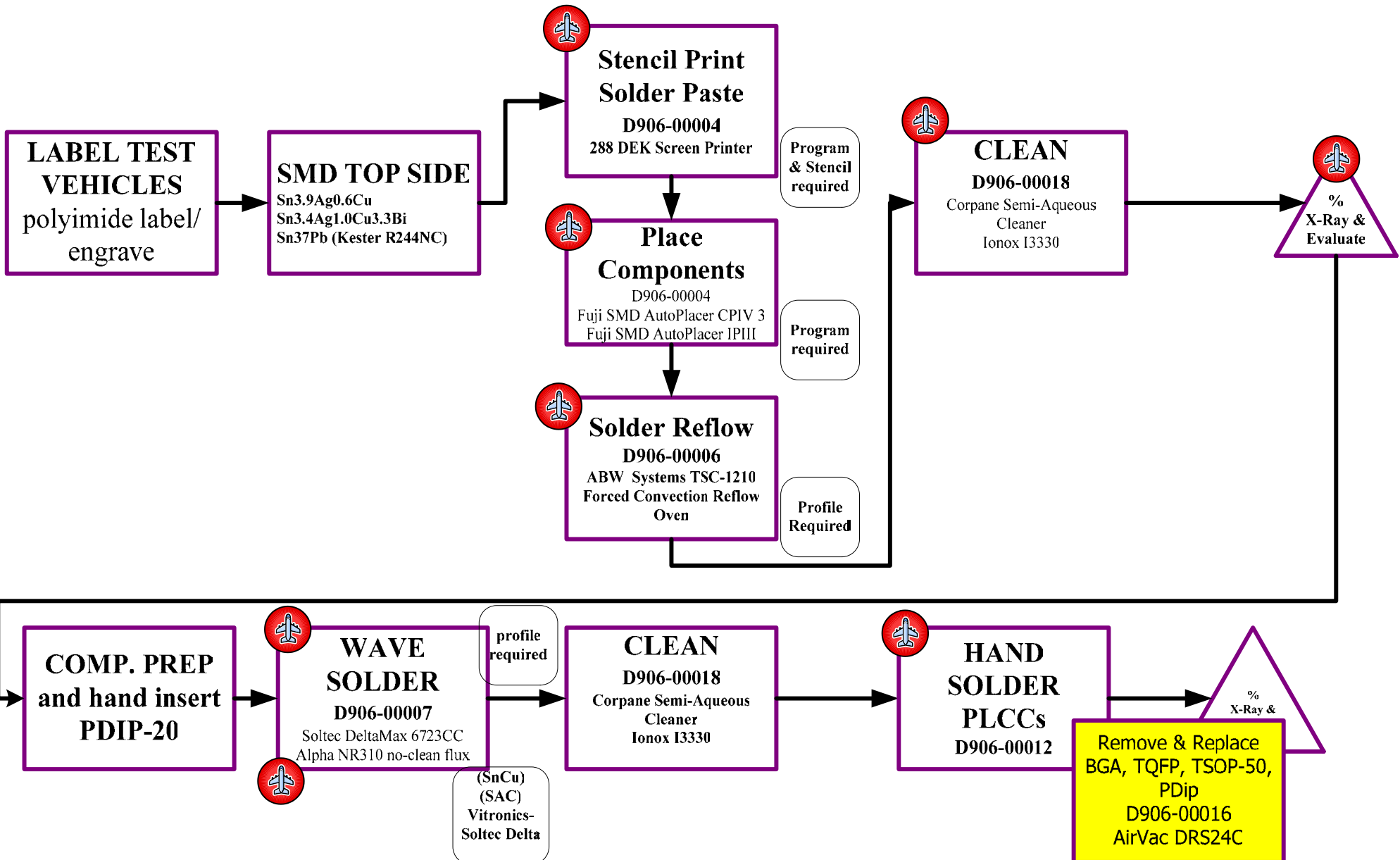


For rework, only examining “Forward Compatibility” (Pb-free rework of a traditional Pb board), not “Backward Compatibility” (Pb rework of Pb-free board)

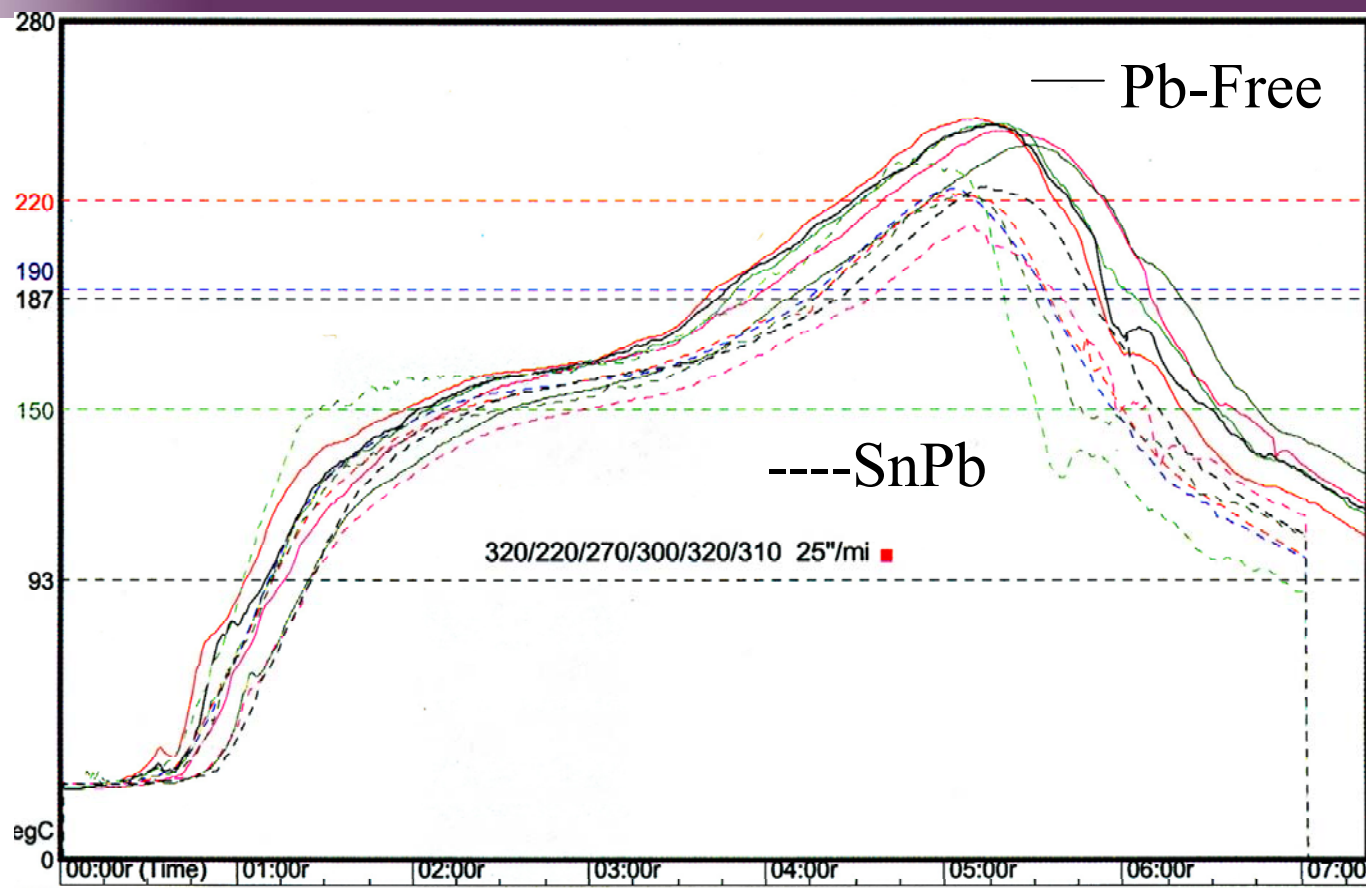


Assembly

Assembly Flow



Reflow Oven Profile Overlay



Standard SnPb Profile

Preheat = ~ 120 seconds

@140-183°C

Peak temperature = 225°C

Time above reflow = 60-90 sec

Ramp Rate = 2-3 °C/sec

Lead-Free Profile

Preheat = 60-120 seconds

@150-190°C

Peak temperature target = 243°C

Reflow:

~20 seconds above 230°C

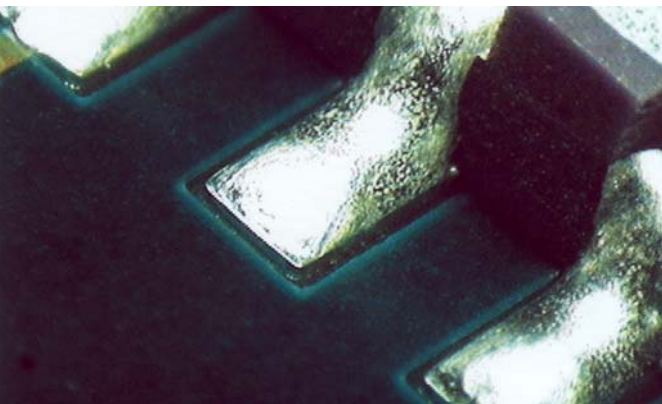
~30-90 seconds above 220°C



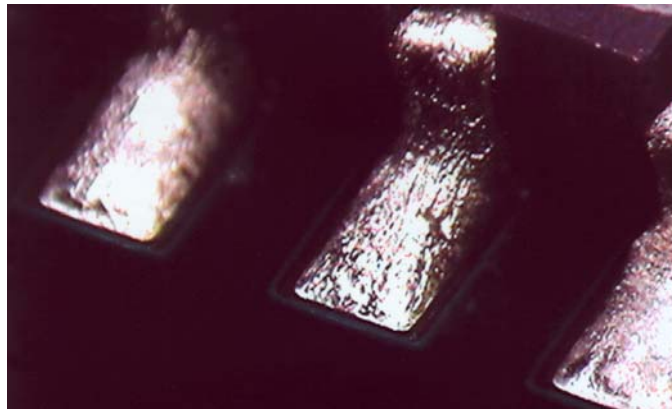
Results

Comparison of different surface finish CLCCs

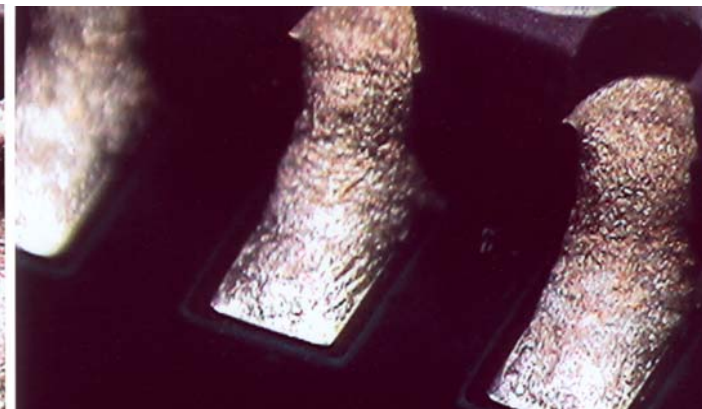
Soldered with SnPb



SN44 U17
SnPb lead surface finish



SN156 U17
SAC lead surface finish

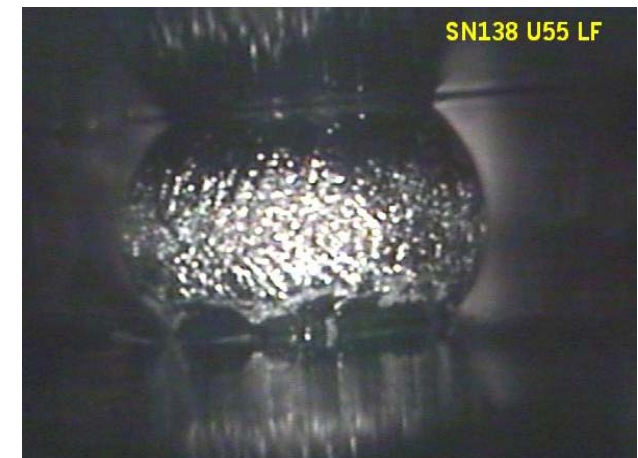
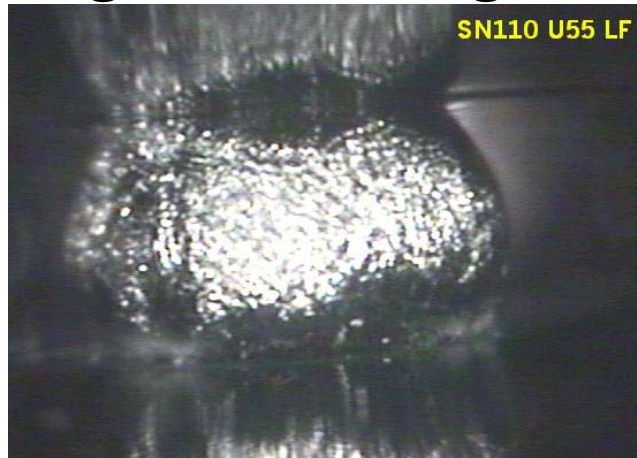
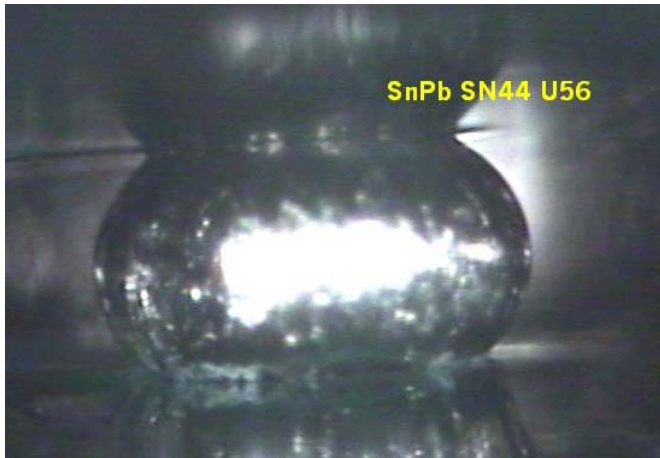


SN182 U17
SACB lead surface finish

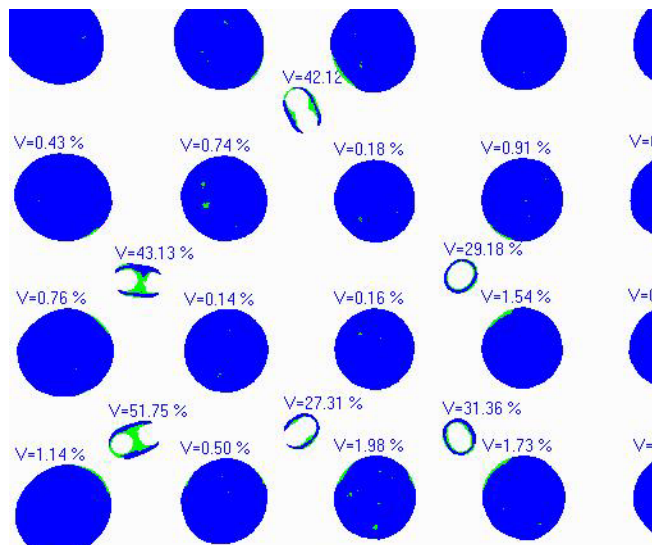
SnPb HASL PWB

BGA comparison

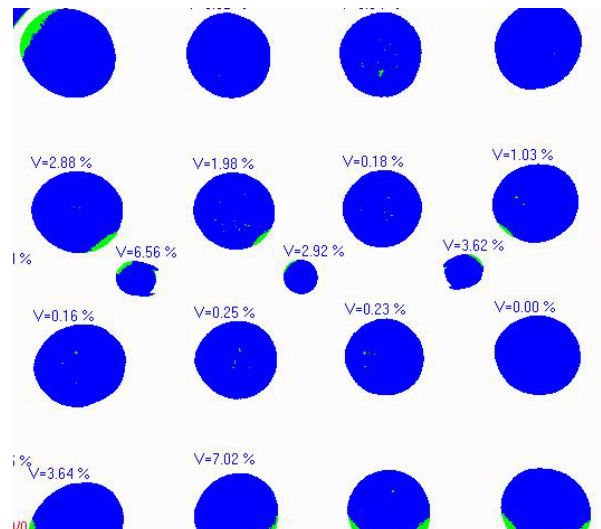
Soldered with SnPb, SnAgCu, and SnAgCuBi



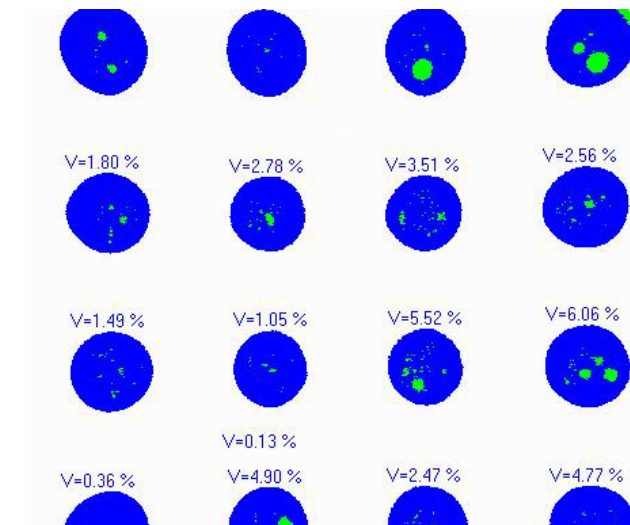
SnPb 'Rework-Control'
SnPb solder/SnPb BGA



'Manufactured'-SAC
SAC solder/SAC BGA

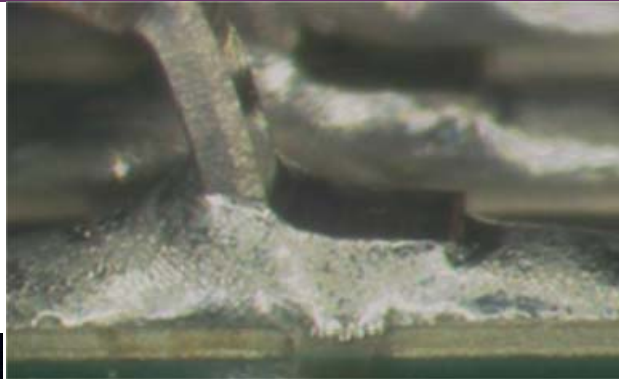


'Manufactured'- SACB
SACB solder/SAC BGA



0.36-12.29 void percent

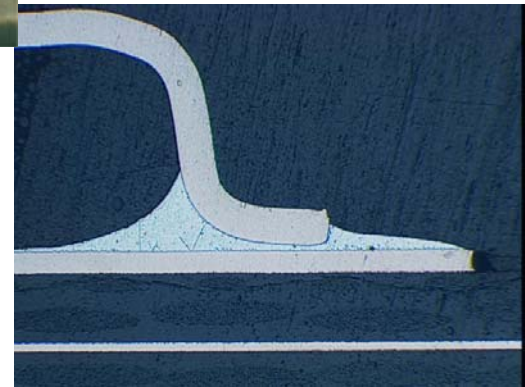
TQFP-208



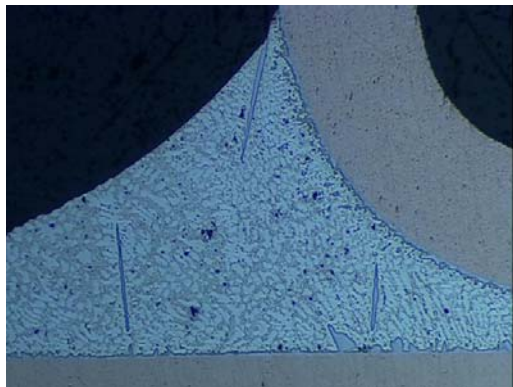
SAC Solder/NiPdAu Finish



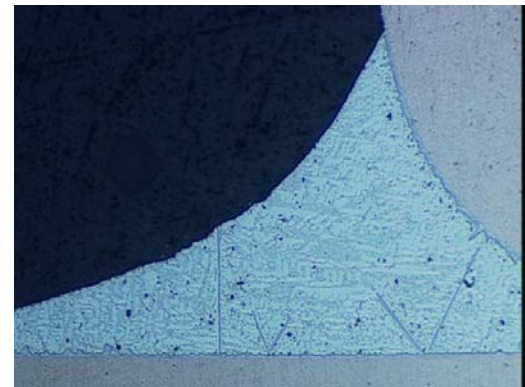
PWB110 - U57 - SAC Solder,
NiPdAu Finish @25x



PWB110 - U3 - SAC Solder,
NiPdAu Finish @25x



PWB110 - U57 - SAC Solder,
NiPdAu Finish @100x



PWB110 - U3 - SAC Solder,
NiPdAu Finish @100x

Conclusions

- Assembly of high reliability electronics using non-standard metallurgies is possible without a total retrofit of the factory.
- Some adjustment of equipment may be necessary where concern for contamination from previous SnPb process dictates (e.g. wave solder pot).
- Significant effort and expense will be required in components management to assure that some metallurgies are not mixed in the factory or in engineering configuration as part numbers change, or not , to reflect new finishes.
- A more closely controlled process management scheme will be **necessary** as process engineers balance the need for higher reflow temperatures with the equally important need for component protection and moisture sensitivity.
- Finally, the huge potential for mixed components from suppliers will drive validation and inspection costs throughout the factory.

Tests

Test		Performed By
Thermal Cycle -20°C to +80°C	IPC-SM-785	Boeing-Seattle
Combined Environments Test	MIL-STD-810F, METHOD 520.2, PROCEDURE I	Raytheon
Thermal Cycle -55°C to +125°C	IPC-SM-785	Rockwell Collins
Vibration	MIL-STD-810F, METHOD 514.5, PROCEDURE I	Boeing-Seattle
Mechanical Shock Test Set I & II	MIL-STD-810F, METHOD 516.5, PROCEDURE I	ACI/ BAE Systems Lansdale
Thermal Shock	MIL-STD-810F, METHOD 503.3, PROCEDURE I	Boeing-Seattle
Salt Fog	MIL-STD-810F, METHOD 509.4	ACI
Humidity	MIL-STD-810F, METHOD 507.4	ACI
SIR	IPC-TM-650, METHOD 2.6.3.3	Boeing-Anaheim
EMR	IPC-TM-650, METHOD 2.6.14.1	Boeing-Anaheim
Characterization		Rockwell Collins

Acknowledgements

The following JCAA/JG-PP companies provided technical support and/or materials that made this effort possible:

- ACI – Pb-free skill training for hand soldering
- BAE Systems Irving – factory time and labor expenses
- Boeing Phantom Works Seattle – technical support
- Florida CirTech, Inc. – materials
- Global Stencil – stencil services
- Heraeus – materials
- Kyzen – board cleaning after Pb-free wave solder
- MSL- translation of design data from Zuken Redac to GENCAD (Version 1.3).
- Rockwell-Collins – board design, procurement of parts and bare boards
- Senju Solder – materials
- Vitronics-Soltec – wave solder machine for Pb-free portion of assembly

Contact Information:

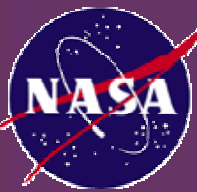
ana.campuzano-contreras@baesystems.com

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Irving, TX 75038
(972)659-2546

For additional JCAA/JG-PP Lead Free Solder Project information,
please visit the following links:

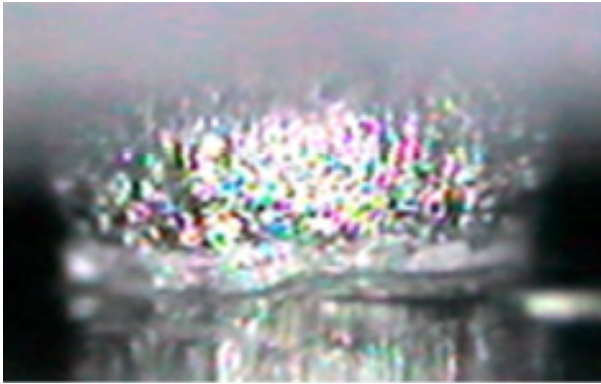
<http://acqp2.nasa.gov/LFS.htm>

http://www.jgpp.com/projects_index.html

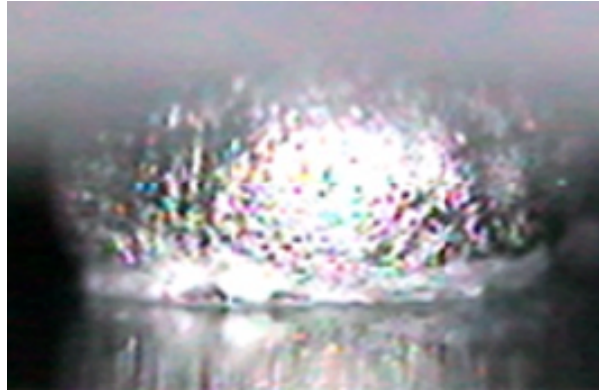


Back-Up Data

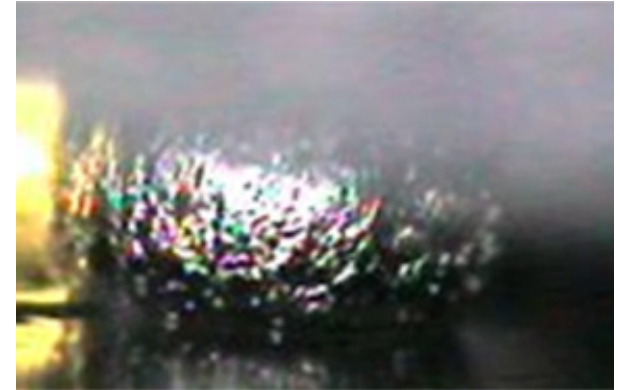
BGAs



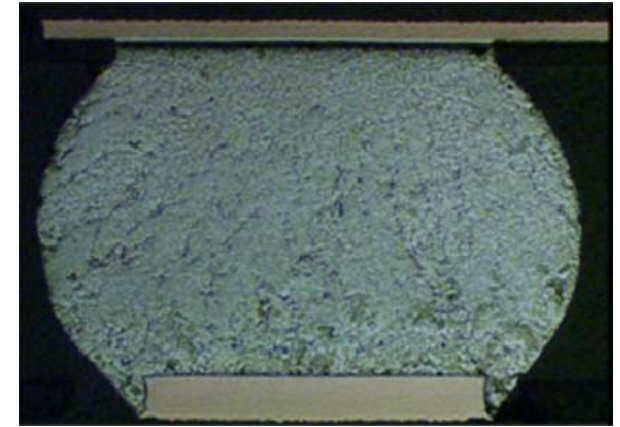
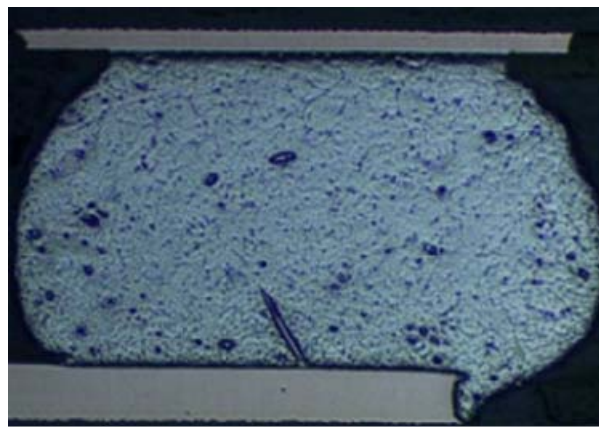
SAC/SAC 110, U18



SAC/SnPb, 110, U2



SnPb/SAC, 41, U18



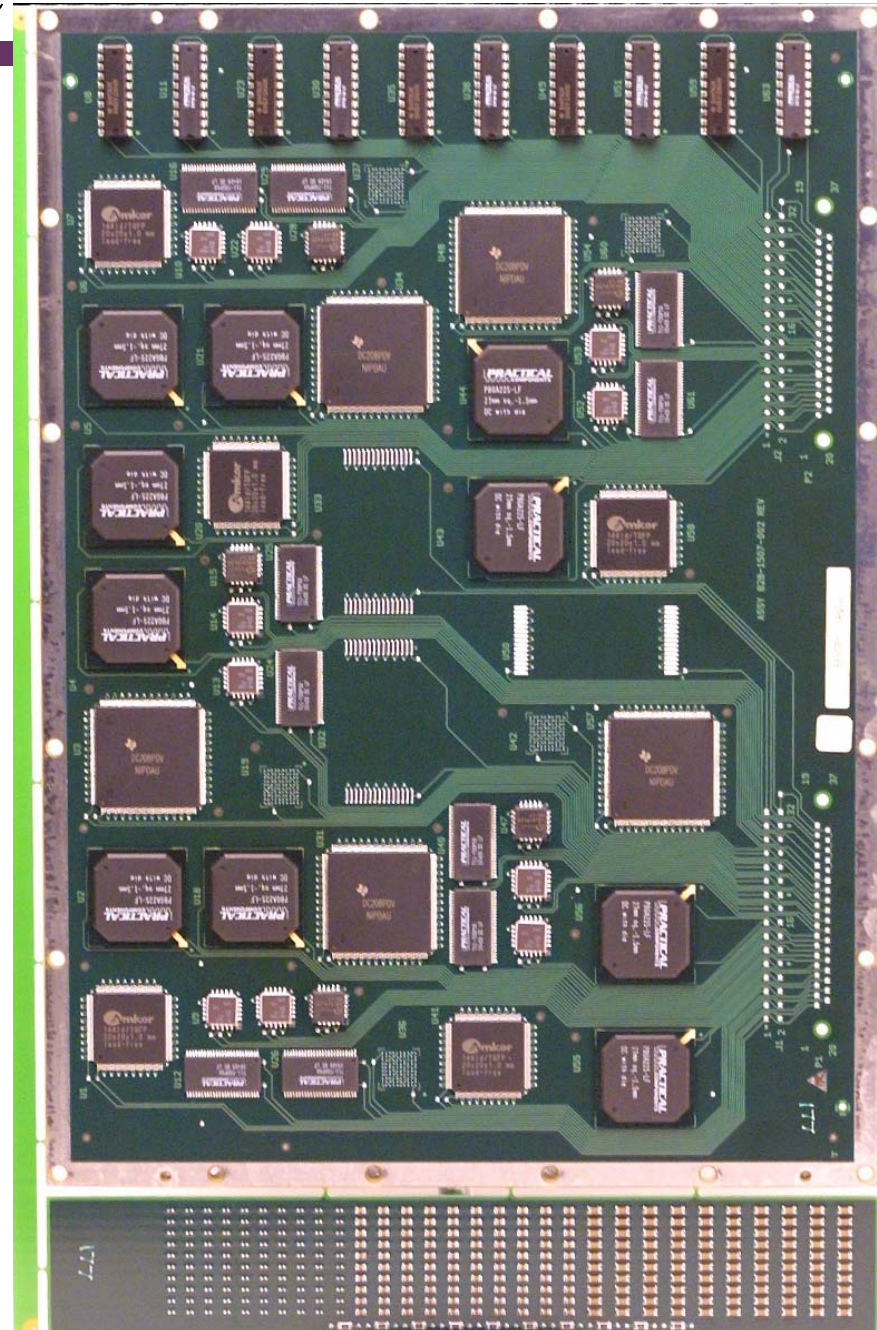
'Manufactured' Test Vehicle

BARE BOARDS

- 14.5"X 9"X 0.09"
- 6 layers
- Immersion Silver (Tg~170°C, GF)
- Solder mask:
- FR4 per IPC-4101/26

ASSEMBLIES

- Surface mount and through hole
- Total Quantity: 119



DEK 288 Solder Paste Screen Printer



Component Placement:



FUJI CP IV used for placement of capacitors and resistors.



FUJI IP3 used for fine pitch, BGAs, and other parts.



Solder Reflow: ABW Systems TSC-1210



Cleaning: Corpane Semi Aqueous Cleaner



X-Ray Evaluation- : Nicolet Imaging Systems 1410Hb



Hand Soldering



Rework (Removal and Replacement)



Wave Soldering: Delta-Max Machine



Wave Soldering @ Vitronics-Soltec: Delta-Wave Machine



BGA removal and replacement: AIR-VAC DRS24C



'Rework' Test Vehicle

BARE BOARDS

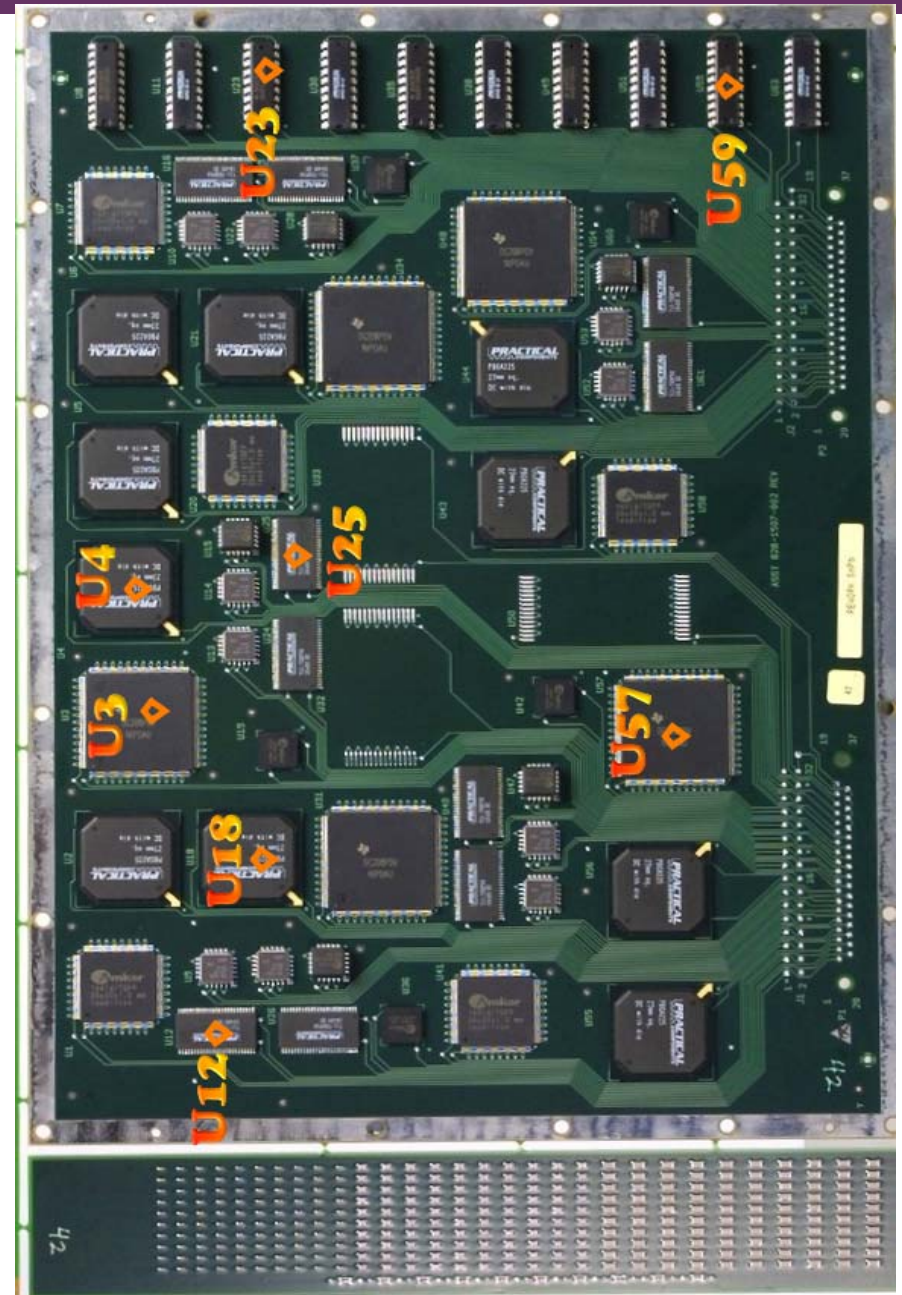
- 14.5"X 9"X 0.09"
- 6 layers
- SnPb HASL (Tg~140°C, GF)
- FR4 per IPC-4101/21

ASSEMBLIES

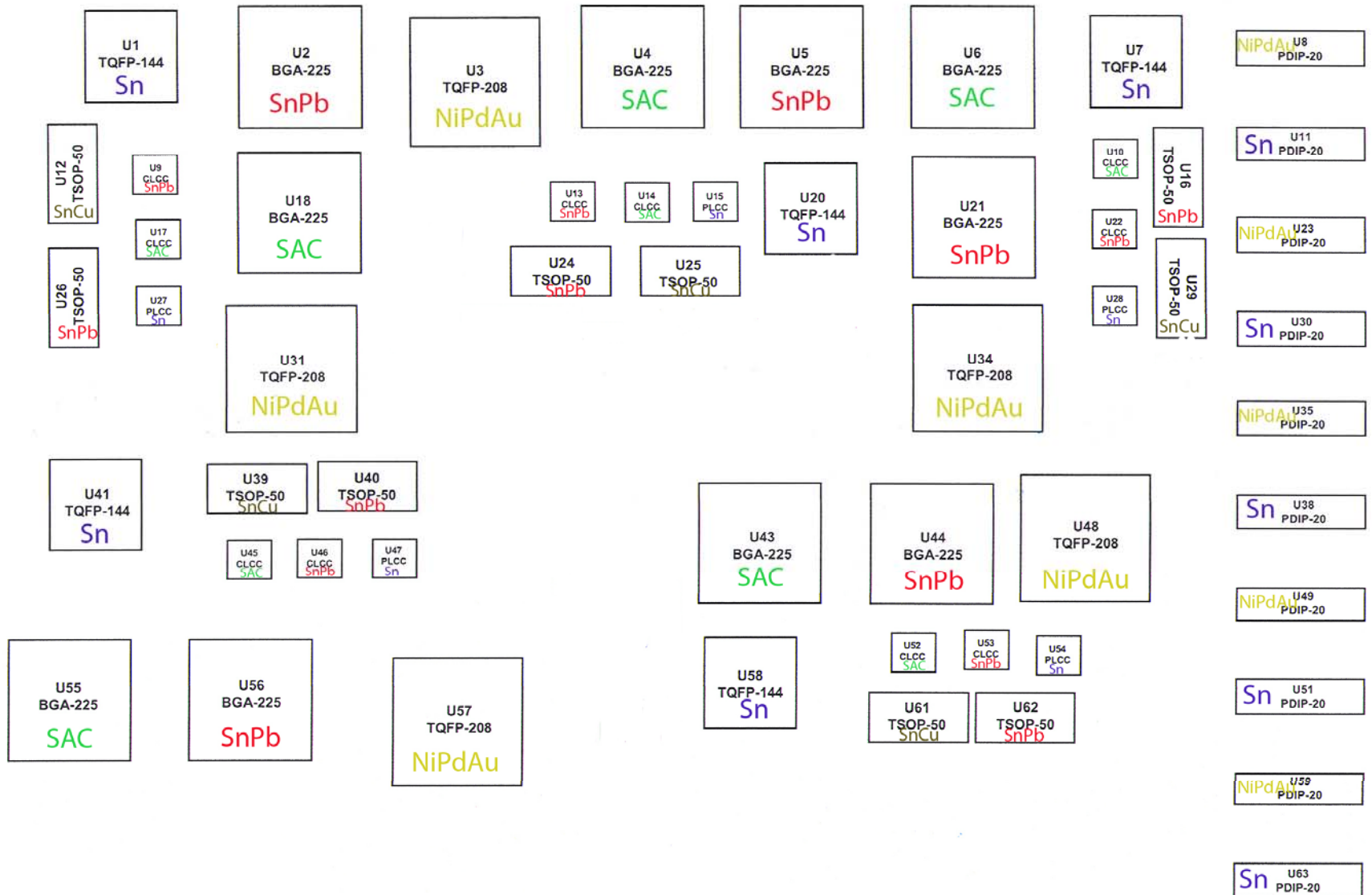
- Surface mount and through hole
- Total Quantity: 86
- Reflow and Wave with SnPb

TEST VEHICLE TYPES

- Rework (8 components) w/SnPb
- Rework with SAC
- Rework with SACB or SnCu

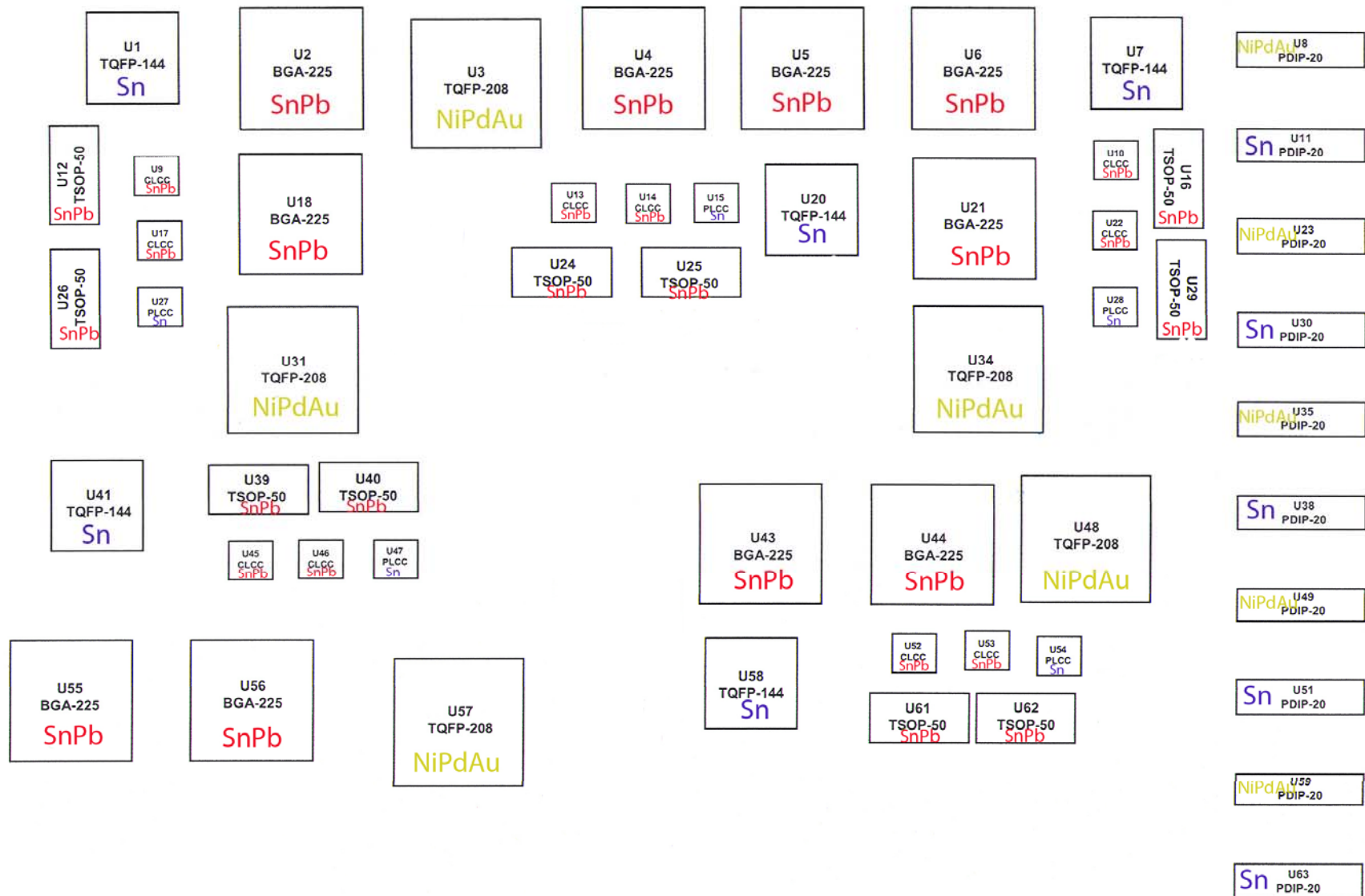


'Manufactured-SAC' Test Vehicle



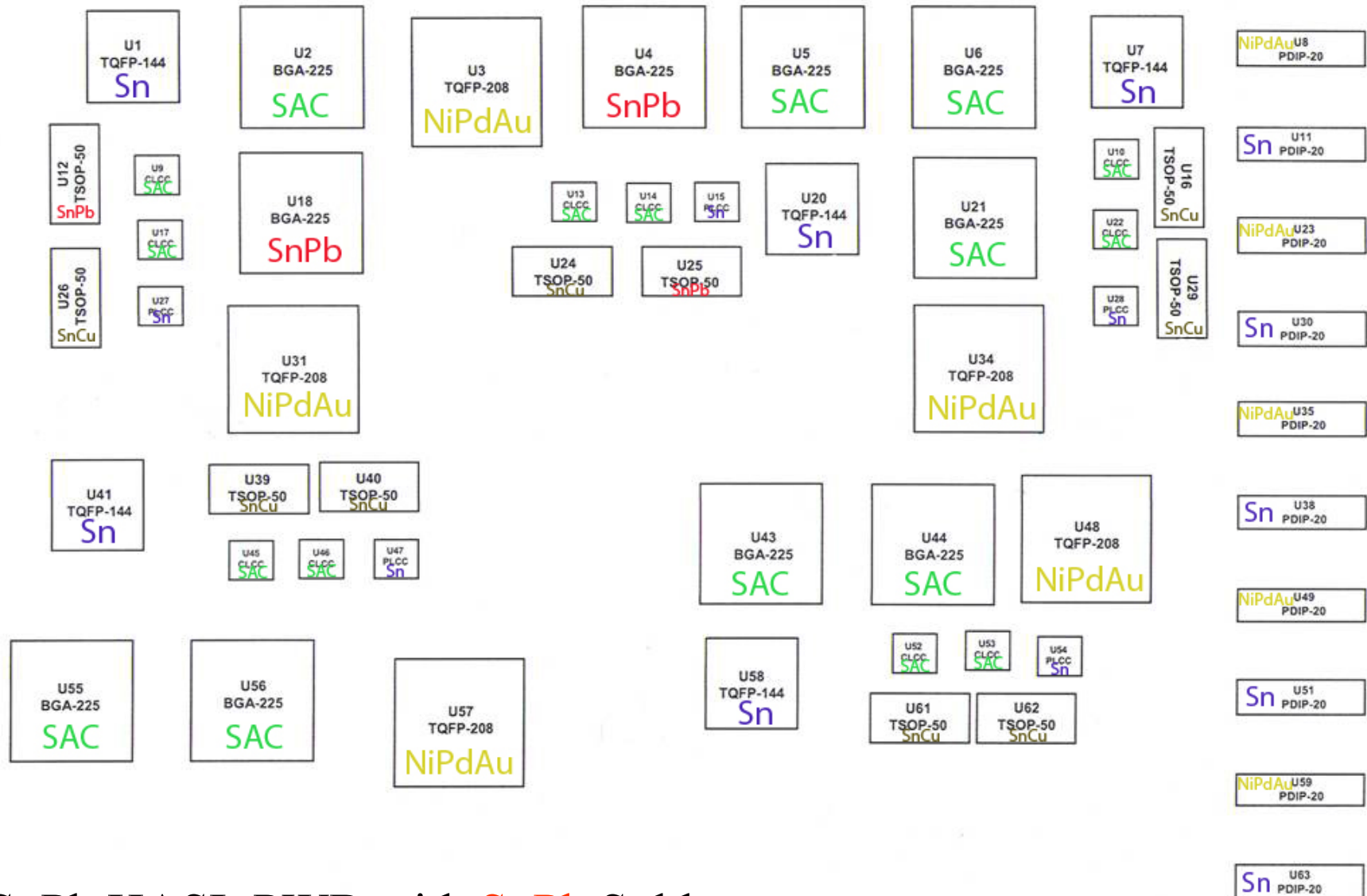
Immersion Ag PWB with SAC Solder

‘Manufactured-Control’ Test Vehicles



Immersion Ag PWB with SnPb Solder

'Rework-SAC' Test Vehicles



SnPb HASL PWB with **SnPb** Solder